

**DEVELOPMENT OF A STANDARD OPERATING PROCEDURE
GOVERNING THE OPERATION, USE, AND MAINTENANCE OF
THERMAL IMAGING CAMERAS**

STRATEGIC MANAGEMENT OF CHANGE

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ABSTRACT

The problem identified for this applied research project was the need by the Mundelein, Illinois Fire Department to develop a standard operating procedure to govern the maintenance, use, and operation of thermal imaging cameras. Having recently acquired a thermal imaging camera for each of our first due apparatus, a procedure was needed to determine the optimum method(s) for using this new technology. Prior to the acquisition of these cameras, the Mundelein Fire Department employed traditional methods in evaluating the scene of an emergency, searching for victims, and extinguishing fires. When utilizing thermal imaging equipment, the mindset of employing traditional firefighting methods would need to be revised. This revision would require a strategic change in the way operations are conducted when thermal imaging equipment was deployed at the scene of an emergency. The purpose of this research was to develop a standard operating procedure which would identify the appropriate situations in which to deploy the equipment, and procedures for maintaining and utilizing thermal imaging equipment. This research employed the evaluative research method to compare procedures and practices currently employed in the field of thermal imaging. The following research questions were identified for use: (a) What practices are recommended to insure the readiness of thermal imaging cameras for emergency operations? (b) In what emergency situations is it appropriate to employ thermal imaging cameras? and (c) What procedures should be followed when operating a thermal imaging camera? The results identified several procedures and practices that would need to be included in a standard operating procedure relating to thermal imaging equipment. Recommendations identified the need to define training standards, the need to review the procedures identified against future standards, and the need for the fire service to develop a consensus standard governing thermal imaging equipment.

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INTRODUCTION

One of the most exciting new technologies available to the fire service today is the thermal imaging camera. Some consider this new technology to be the most promising tool for improving firefighting abilities second only to fire sprinkler systems and automatic notification systems (“Image Is Everything”, 1998). As a result, this equipment is now gaining widespread acceptance in today’s fire service. Thermal imaging cameras are becoming readily available to more fire departments as the cost of the equipment decreases and funding sources are identified. Thermal imaging cameras are allowing our firefighters to do their jobs more quickly and efficiently when called upon and thereby better enable the fire service to serve the public.

This technology allows firefighters to “see” through smoke by converting thermal energy to a visual image. “Thermal imaging cameras equip firefighters and other emergency personnel with a whole new way of looking at the world. In simplest terms, thermal imagers operate similar to the human eye, but they are much more powerful” (Love, 1999, p. 33). Thermal imaging equipment operates much the same way a digital camera does with one important exception. A thermal imaging camera measures the relative difference in the various infrared emissions of objects, and through a microprocessor converts these differences into a visual representation.

Thermal imaging equipment was first used by the fire service in the 1970’s but did not receive widespread acceptance until 1998 (Stevens, 1999). The officers of the Mundelein Fire Department, in reviewing periodicals and discussing this technology with current users of thermal imaging equipment, identified the benefits the acquisition of such equipment would present to the firefighters and citizens of our community. Planning began in 1998 to enable us to obtain this new equipment and funds were made available in the 1999/2000 fiscal year budget

for the purchase of two thermal imaging cameras with an option for a third. As part of a research project for the Executive Fire Officer Program for the National Fire Academy in 1999, Chief Randy Justus developed specifications that resulted in the purchase of a FLIR thermal imaging camera for each first due engine company in mid 2000.

Used properly, this new equipment can be a benefit to citizens and our firefighters by reducing rescue times by as much as 50% (Siru, 1996). Used improperly, it could cause our firefighters to “become too dependent on the device and in time of failure become totally disoriented” (Crickenberger & Sojka, 2000, p. 66). Improper use could lead to increased danger for our firefighters and those we are protecting. To avoid this possibility our firefighters will need to make a strategic change in the way they approach dangerous situations while using this new technology. Our staff will also be required to make strategic changes in the way personnel and tasks are assigned.

In order to provide direction and advance the use of the thermal imaging devices, a standard operating procedure is needed. This procedure should be clear, concise, and provide a framework from which to operate safely and efficiently. The problem identified in this research was the need for the Village of Mundelein Fire Department to define a standard operating procedure for thermal imaging equipment. Having recently acquired thermal imaging equipment, the department began training in order to become familiar with operating the equipment. The manufacturer in the form of classroom, videotape and compact disc presentations provided initial training. Once our firefighters were familiar with the basic operation of the thermal imaging cameras, they began to gain experience by using the equipment under controlled situations inside burn structures. Once all personnel had received this training, the imagers were placed in service. It quickly became apparent that a standard operating

procedure would be required in order to provide guidelines for insuring the readiness of the devices, the appropriate situations in which to employ the cameras, and procedures governing the operation of the cameras.

At the present time “No fire service standards have yet been set for thermal imagers” (Woodworth, 2000, p. 84). Woodworth (2000) recommends that other fire service agencies be contacted to determine the various experiences encountered they have encountered and what procedures they have implemented to govern the equipment.

The purpose of this research is to assist in developing a standard operating procedure that will address the following issues:

1. What practices are recommended to insure the readiness of thermal imaging cameras for emergency operations?
2. In what emergency situations is it appropriate to employ thermal imaging cameras?
3. What procedures should be followed when operating a thermal imaging camera?

BACKGROUND AND SIGNIFICANCE

In May of 2000, the Mundelein Fire Department was able to acquire thermal imaging cameras for deployment on first due engine companies. This acquisition was the result of specifications that had been developed by researching the available information. The research was completed in October of 1999 as a part of an applied research project completed by Randy C. Justus, a candidate in the Executive Fire Officer Program at the National Fire Academy in Emmitsburg, Maryland. Once the specifications were reviewed and approved for bid by the Village Board of Trustees, the specifications were sent to the various manufacturers of the equipment.

In April of 2000, the competitive bid process resulted in an award being made to FLIR Systems of Portland, Oregon for the purchase of two FireFLIR™ thermal imaging cameras. The Mundelein firefighters were trained in the use of the cameras, in both classroom and live burn settings. Once all firefighters were trained, the thermal imaging cameras were placed in service in each of our two first due engine companies. It was soon noted by the command staff that the thermal imaging cameras were being maintained differently by each of the three platoons, not being used consistently by the three platoons, and that guidelines covering the use of the devices were needed to insure the safety of our personnel and the most efficient use of the devices.

Incorporating the use of thermal imaging equipment into emergency situations would require our firefighters to make a strategic change in the way they operate. While traditional skills would need to be maintained, the firefighters would need to embrace new procedures in order to optimize the various benefits associated with the use of thermal imaging equipment. This research project would require use of techniques learned in the Strategic Management of Change Class taught at the National Fire Academy as part of the Executive Fire Officer Program.

Village of Mundelein, Illinois

The Village of Mundelein is located in Lake County, Illinois, one of the collar counties surrounding Cook County and the City of Chicago. The Village of Mundelein was incorporated in 1909 and existed as a rural community until the 1960's. Due to increasing population in the Chicagoland area, and the subsequent improvement in transportation routes as required by the growing suburban population, Mundelein experienced rapid growth and the rural atmosphere quickly changed to that of a more suburban community. During the transformation from rural to suburban, Mundelein's population grew rapidly. In the 1950's the population was approximately

1,500 persons. According to the most recent information available (special census of 1997), the population now totals nearly 30,000 residents. The Village while largely residential also has a strong light manufacturing, office, and retail base. There are currently more than 7,500 structures in the Village with the construction of additional residential and office type buildings continuing. Mundelein enjoys a diverse population of approximately 76% White, 20% Hispanic, 1% Black, and 3% Other (special census of 1997). Our median household income is \$50,466. This is reflected in the housing market with homes priced between \$150,000 and \$750,000. The diverse variety of structures in the Village provides challenges to our firefighting abilities and requires that the Village adapt new techniques to meet the expectations of our residents.

Mundelein Fire Department

Mundelein's Fire Department was established in 1926. The original firefighters were volunteers from within the community. It was not until 1970 that the first career employees were added. The Department staffing is comprised of both career firefighters and paid-on-call firefighters. Currently the Department has 24 career employees, all of which are certified by the State of Illinois at a minimum level of Firefighter II and Emergency Medical Technician, Paramedic (EMT-P). The paid-on-call force is comprised of 26 employees, all of which are certified by the State of Illinois at a minimum level of Firefighter II and Emergency Medical Technician, Ambulance (EMT-A). Several paid-on-call members have also attained the certification as EMT-P. The Department operates two engine companies, one aerial ladder company, one heavy rescue squad/pumper company, and maintains one reserve engine. In addition, the Department operates 4 paramedic ambulances. The Department operates from two facilities which were constructed during the past 2 years. The new facilities replaced the single

station from which the Department originally operated. The Village's geography provides for a four-minute fire department response to 95% of the territory protected. Strong mutual aid agreements with neighboring fire departments contribute to the overall ability of the Department to deliver quality services.

The department also provides emergency paramedic ambulance service to the residents. Hazardous materials containment and mitigation, confined space rescue, trench rescue, structural collapse rescue, weapons of mass destruction response and water rescue/recovery are provided in cooperation with the Lake County Specialized Response Teams, Inc., a governmental entity which was created by the cooperative efforts of all twenty-six fire departments in Lake County with the goal of providing cooperative, specialized response capabilities beyond the means of any one of the member fire departments.

In late 2000, thermal imaging cameras were acquired for deployment at both of the Village's two fire stations. The cameras were purchased from the corporate funds of the Village with the intent of increasing the fire departments capabilities when responding to the needs of the citizens. The acquisition of this new technology has resulted in the realization that the Department must effectively manage this strategic change and modify the way we traditionally conducted firefighting operations. "Set up a workable SOP for their (thermal imaging camera) proper use, and remember that conventional searches still need to be part of your rescue plan" (Hollins, 2000, p. 26) is a recommendation that must be included in any standard operating procedure dealing with thermal imaging cameras. This new technology requires the use of non-traditional methods and behaviors in combination with traditional tactics when responding to fire emergencies.

LITERATURE REVIEW

Thermal imaging equipment has been utilized to a limited degree in the fire service since the 1970's. Since that time many improvements have been made that have resulted in the equipment being more reliable, smaller, and lighter in weight. At the same time, the cost of the equipment had dropped to the point that many fire departments are now able to acquire this type of equipment. Unfortunately, according to Woodworth (2000) no consensus standards have been adopted relating to thermal imaging cameras. The goal of this research is to identify procedures and practices that should be incorporated into a standard operating procedure that will serve as a guideline for the Village of Mundelein Fire Department until such time as consensus standards are adopted.

Maintaining Readiness Of Thermal Imaging Cameras

Determining the pre-use and maintenance requirements of the thermal imaging equipment is the basis for insuring that the devices will be ready for deployment at the scene of an emergency incident. This category includes being familiar with the equipment and the maintenance requirements (daily, weekly, and periodic), being familiar with the capabilities of the equipment, and understanding how to return the equipment to operational capable status after each use.

“The absolute first objective after purchasing a thermal imaging device should be to have all personnel properly trained in its use” (Woodworth, 1997b, p. 16). Training should consist of a variety of classroom and practical sessions. These sessions will allow potential users to become familiar with the equipment. When preparing to place this equipment in service one

should consider the training that has been provided and ensure that personnel are comfortable in the operation of the equipment.

Steven P. Woodworth (1997b, p. 16) in his series on thermal imaging equipment equates the use of thermal imaging equipment to the use of self-contained breathing apparatus:

“I do not believe that there is a fire department in the country that would hire a firefighter and place him in a situation that requires using a self-contained breathing apparatus without first having trained him in its proper use. The same would hold true for thermal imaging devices (unfortunately, this is not the case).”

Training sessions would then advance to a point at which the potential users are required to demonstrate proficiency in using the equipment. The training division of the entity should be required to develop a specific training regiment and continue to provide regularly scheduled training on the use of the thermal imaging equipment.

“This tool, like any other tool, is only as good as the firefighter operating the unit. Knowing how to operate a thermal imaging device properly can cut in half the time required to search a given area and increase the safety of the search operation while increasing the search’s effectiveness” (Woodworth, 1997c, p. 24)

The manual for the particular thermal imaging camera(s) employed by the fire department should serve as the basic reference in determining the condition of the camera and the normal settings of the various adjustments. The Mundelein Fire Department purchased two FireFLIR™ thermal imaging cameras. A review of the FireFLIR™ Orientation Manual (FLIR Systems, 2000) indicates that the user should be familiar with the following:

- Range switch. This switch will optimize the image for different ambient temperature conditions. The switch has three modes, auto temperature range, high temperature

range, and low temperature range. This switch is to be set in the auto range mode for most structural firefighting situations. The high and low ranges are available when using the imager for specialty operations such as hazardous materials incidents, search and rescue operations, and wildland firefighting.

- Color switch. This switch will allow the user to toggle between a black and white or color display. The black and white display has proven to provide a much clearer image in most firefighting operations. The color display is useful for visualizing smaller heat differences that one would expect to find in a hazardous materials spill, electrical fault situation, or any incident involving near normal temperatures. This switch should be maintained in the black and white setting for most structural firefighting situations.
- CAL switch. This switch is not currently functional. It is available for future upgrades that may become available for the FLIR™ camera.
- RAD (Radiometry) switch. When this switch is activated, the imager can measure and display the temperature of the object on the display screen. The Mundelein Fire Department did not purchase this option, making this switch inoperable.

Battery maintenance is a critical issue relating to the operation of the FLIR™ camera. Each FLIR™ thermal imaging camera is delivered with four 2 hour batteries and a charging device capable of charging four batteries simultaneously. FLIR™ Systems (2000) recommends that the battery be removed from the unit when not in use and that the imager be stored in the protective case until needed. The batteries should be stored in the battery charger when not in use. It is also recommended that the user always carry a spare battery for use should the operating battery fail. Protocol should also dictate that each time the firefighter operating the

thermal imager requires recharging of their self contained breathing apparatus, that a fresh, fully charged spare battery be installed (Woodworth, 1997a).

Maintenance of the lens and display area is also mandatory. The lens of most cameras is protected with a special coating which provides additional protection of the optical crystal germanium lens. In the FLIR™ system this covering is a diamond coating that will protect the camera from scratches and everyday hard use. The lens of the camera should be coated after each use with an anti-fog solution. This solution will keep the lens from becoming cloudy or foggy as the camera is moved through various temperatures. The lens should also be wiped with a damp cloth after each use to remove any particulate matter (Humphry, 2000). Failure to treat the lens or clean the lens will cause the display to be less than optimal, as the particulate will reduce the ability of the focal plane array to sense the various temperatures accurately (FLIR Systems, 2000, p. 14).

FLIR Systems recommends that in addition to the above procedures the thermal imaging camera should be checked daily. This check should include insuring that there are no deformities in the battery packs, that all warning labels are properly installed, that the mounting clip and strap are secure and operational, and that the camera initializes properly (FLIR Systems, 2000, p. 37).

When placing the unit in storage on the apparatus, it is recommended that the FireFLIR™ be stored within the hard case provided, along with the cleaning supplies. This will ensure that the thermal imager is ready for immediate access. Storage temperature should be -10°C (14°F) to 70°C (158°F), (FLIR Systems, 2000, p. 36).

While maintenance items such as cleaning and insuring the thermal imager is adjusted to meet local practices, are mandatory, opening the imager and attempting to repair the delicate

circuitry is not recommended. Humphry, (2000, p. 13) states “Service and repair other than those specified in the operating guidelines shall be performed by the authorized agent.” FLIR Systems, (2000) recommends that any maintenance other than daily servicing is to be done by the manufacturer of the equipment.

In What Situations Should Thermal Imaging Cameras Be Deployed

The use of thermal imaging equipment in firefighting situations allows many benefits. According to Kosiarski, (1993), “Potential benefits of using the camera are:

- Reduced fire damage
- Water damage reduced
- Overhaul damage reduced
- Victims successfully saved by search team
- Death and injury to firefighters reduced
- Reduction in fire equipment requirements through less wear on equipment
- Reduction in the number of fires that grow beyond control”

“Thermal imaging equipment is primarily being used in structural firefighting in four ways. They are size-up, fire attack, search and rescue and overhaul” (Richardson, 2000, p.3). Additionally, thermal imaging has been used successfully in determining the location of fire in heavily layered commercial roofs, utility pipe chases and mechanical duct systems, and hidden fires in cocklofts and large commercial areas (Endrikat, 2000).

Thermal imaging equipment was originally designed as a visual-enhancement technology for firefighting. Thermal imaging equipment is now being used for a host of other emergency situations. This equipment was successfully used to track an oil pipeline break, which resulted in

an oil release into the Gulf of Mexico. In another situation, thermal imaging equipment was able to avoid a pending disaster by uncovering an ignition source that could have caused an explosion to occur. A ship lost steering control and crashed into a mall, causing the mall to collapse. The mall collapse caused a natural gas main to rupture and the thermal imaging camera detected an ignition source which was then quickly extinguished, preventing a compounding of the incident. In yet another instance, during the initial stages of rescue at the Oklahoma City bombing, thermal imaging was used to locate cavities where people might be found alive (Love, 1999).

In hazardous materials emergencies, thermal imaging cameras are capable of confirming, from the outside of a container, the level of the liquid inside. It is important to consider however that containers appearing one solid color, are either empty, full, or well insulated. If the imager is equipped with a temperature display, this readout can determine if the material is reaching its boiling point or its flash point (Richardson, 2000). This thermal imaging ability can also assist firefighters in applying water to cool the hot spots on tank type vehicles and containers (Glover, 1999).

Aircraft incidents present another opportunity for maximizing the abilities of thermal imaging equipment. In fog or low-visibility conditions, responders are able to quickly zero in on the crash site and heat sources and aid the victims much more rapidly (Wagner & West, 1998). This same method can also be employed when attempting to locate persons in open or wilderness areas (Charlottesville, VA Fire Department, 1999).

A Fire Department in Florida includes the use of thermal imaging cameras to assist in locating victims on the surface of water, specifically at night, in their standard operating procedure governing the use of thermal imaging equipment (Cedar Hammock Fire Department, 1998). One noteworthy exception to the ability of thermal imaging equipment is the inability of

the equipment to locate a victim below the surface of the water. This is due to the fact that infrared radiation cannot penetrate water or glass (Wagner & West, 1998).

Thermal imaging cameras are excellent tools for identifying areas affected by lightning strikes, electrical power surges, electrical lines, or wires with abnormal current draw (Richardson & Scholer, 1999).

When conducting aerial operations, the thermal imaging camera can identify obscured power lines and other obstructions. The camera will also allow persons on the ground to maintain visual contact with the firefighters on the aerial ladder (Stevens, 1991).

The FireFLIR™ Orientation Manual (FLIR Systems, 2000) recommends using thermal imaging cameras to:

- Identify hoses and openings in floors, ceilings, and roofs
- Watch training sessions evolve
- Identify fall and trip hazards
- Identify signs of potential structural collapse
- Use as an exterior viewing platform for size-up
- Identify loose electrical connections

As important as it is to determine when to use a thermal imaging device, it is equally important to know when not to use a thermal imaging camera. These devices should not be used in potentially explosive atmospheres unless it is certified as intrinsically safe as their use may cause ignition of an explosive atmosphere (Humphry, 2000). One final contraindication would be to avoid pointing the camera at heat sources when not turned on, and to never point the lens of the imager at the sun. Both of these actions could severely damage the sensing components and lens of the camera (“Image Is Everything,” 1998).

What Procedures Should Be Incorporated In The Operation Of A Thermal Imaging

Camera.

Once it is determined that a thermal imaging camera is to be utilized at the scene of an emergency a procedure is necessary to insure the proper operation of the device and provide for the safety of the firefighters using the device. “Every firefighter who will use a thermal imaging camera must be trained in its use, know how to interpret what is seen and be re-taught the basic firefighting fundamentals” (Crickenberger & Sojka, 2000).

Of primary importance, the operation of the thermal imaging camera should be in accordance with the manufacturers recommendations. Other factors such as search patterns, interpretation of the visual display, and reinforcing traditional skills are also necessary considerations for insuring the safety of the firefighters and the citizens.

Operating instructions for the FireFLIR™ are actually simple. There is no actual on/off switch. To power the unit up, the battery is simply slid into place. Once the battery is in place and is making contact, the unit begins a self-diagnostic check which is indicated by the display screen turning red. Once the diagnostic check is complete, a thermal image of whatever the camera lens is aimed at will appear. The following items will then be displayed in the view area:

- Power indicator. This is an icon that displays the approximate battery charge. The battery will, under normal operating conditions power the unit for up to two hours. Charge remaining in the battery is indicated by a white triangular icon that moves on a horizontal axis from fully charged (green area, maximum two hours operating time) to yellow (caution area indicating approximately thirty minutes of power remaining) to red, indicating inadequate battery charge and that the unit is about to shut down. Should the battery icon appear white with a black question mark (?), the battery is

malfunctioning or unstable and must be replaced before use. The battery icon is always visible in the display area of the camera and requires no adjustment.

- Temperature indicator. This icon becomes visible in the viewing area should the internal temperature of the camera reach an elevated level. This icon is represented as a “thermometer bulb” which is not visible until the internal temperature of the camera approaches an unsafe level. A yellow icon indicates that the internal temperature of the camera is approaching an unstable level. Should the icon turn red, failure of the camera is imminent. Should the temperature icon appear white with a question mark (?) the internal temperature sensor has failed and is not reliable. In all three cases (yellow, red, white) the firefighters using the camera must immediately exit the area or structure. This icon also requires no adjustment.

(FLIR Systems, 2000).

The FireFLIR™ is capable of being either mounted on the firefighters helmet or carried by hand. There are advantages when using either the helmet-mounted or the hand-held method when employing the thermal imaging camera. The advantage of the helmet-mounted configuration is the ability to have both hands free for interior fire attack or search and rescue operations. This method also allows the firefighter to carry another tool or advance a hose line to the fire. The hand-held method provides greater versatility by allowing the camera to be passed quickly from one firefighter to another while also allowing the firefighter to have the choice of a thermal view (using the camera) or a natural view (normal eyesight) (Little, 1999). For the purposes of structural firefighting, it appears having the thermal imaging camera helmet mounted would benefit the Mundelein Fire Department’s typical three-person company. When

approaching other types of emergencies, it may be beneficial to use the thermal imager in the hand-held mode.

When using a thermal imaging camera for search and rescue operations under fire conditions, a methodology must be determined for conducting the search. The traditional method of searching in heavy smoke conditions requires the firefighter to crawl on hands and knees, sweeping the floor in an attempt to locate a victim. When utilizing thermal imaging technology it is important to understand how the ability to move quickly and with infrared vision changes a firefighter's behavior. This behavior change can cause the firefighters to not realize the increased danger in a rapidly changing environment. Crickenberger & Sojka (2000) believe these behavior changes include firefighters speeding up the search process, the tendency to stand as a sense of vision is provided, and the tendency to become too dependent of the technology. Each of these tendencies can produce disastrous results. Speeding up the search can cause the firefighter to enter deeply into the building without an air supply to support their exit. The tendency to stand up will cause firefighters to be exposed to superheated smoke and gases as well as providing the firefighter with a false sense of security or it could cause firefighters to trip or fall. Possibly the worst tendency is the over dependence on the thermal imaging equipment. Should the equipment fail, the firefighter could become totally disoriented and lost. Firefighters must remember that the thermal imaging camera is a tool and that standard training tactics must be applied to ensure continued safe operations in case of imager failure.

Lack of adequate personnel training can render a thermal imaging camera useless (Cook, 2000). It must be reinforced that thermal imaging cameras are not a tool designed to replace good fireground tactics, which include utilization of ventilation techniques and deployment of

search lines. Thermal imaging equipment is not intended to reduce staffing levels (Woodworth, 1996).

While acknowledging that the proficiencies of traditional awareness and tactics are required, thermal imaging equipment necessitates adapting new methods when searching for victims or attacking the fire. Search methods identified include the Oriented Search, the IR-led Search, and the Point-To-Point search.

When utilizing the oriented search, the search team works their way to the room to be searched using standard techniques (wall orientation, making all turns in the same direction, etc.), with the benefit of the thermal imager enhancing the orientation of the crew. When reaching a room or area to be searched, the firefighter without the imager remains at the door and oriented to the teams escape route. The firefighter with the imager moves into the room, looking back every few feet to insure orientation with the door. Once the room has been viewed, the firefighter with the imager returns to the doorway and the team moves on to the next room (Cook, 2000).

When utilizing the IR-led search method, the firefighter with the imager leads the search team through the structure while passing along information to the team. Should a victim be located that cannot be reached from a position on the wall, the firefighter with the imager remains at the wall and directs the firefighter to the victim. Should the imager fail, the searching firefighter is guided back to the firefighter with the imager by following the sound of his voice (Woodworth, 1997c).

The Point-to-Point search involves the imager operator identifying a landmark and moving the team to that point. The team searches along the way. Once this point is reached, the operator scans the area again for the victim and also identifies a new landmark. The team then

proceeds to the next location. This type of search is more commonly conducted utilizing handheld imagers (Woodworth, 1997c).

Woodworth (1997c) also recommends utilizing a six-sided scan approach for search and rescue operations. This is accomplished by stopping upon entering a room or area and, using the imager, scanning the room starting from the extreme top right corner to the top left corner. The imager is then pointed midway down the wall and a second scan is made from the extreme right to left. Finally, the imager is pointed toward the floor and a third scan is made from the extreme right to left. This search pattern is sometimes referred to as a “S” or “Z” search method.

When operating in a fire attack mode, a six-sided scan approach is modified from above. The firefighter operating the imager scans the room from extreme left to right at the floor level. A second scan is made from the extreme left to right at the ceiling level. Finally, a third scan of the floor is made, scanning from the extreme left to right. This technique provides an opportunity to locate the victim while assessing the structural integrity of the area and developing fire conditions (Woodworth, 1997b).

Conditions can change rapidly in a structure fire. Firefighters using thermal imaging equipment must be able to quickly interpret the images represented on the display. Failure to do so can quickly become fatal for a firefighter (TIC Testimonial, 1999). A “flashover” (the ignition of all combustible surfaces in a room) is an extremely dangerous condition that can happen rapidly. In order to survive, a firefighter must be able to distinguish this phenomenon quickly. In predicting flashover, the firefighter using the thermal imager will visualize heat build up in a given area. The entire area will eventually appear white in the image. This indicates that the entire area is heating up and results in the thermal imaging device being able to detect little or no thermal contrast. Prior to flashover, the thermal layer will appear as “water flowing in a

creek.” This is the image is of the superheated fire gases. Unchecked, flame may be seen penetrating through the thermal layer. If water cannot be applied at this point, a hasty retreat must be made as flashover is imminent. Should flashover occur, the firefighters operating the thermal imaging device will lose vision as the entire room becomes one temperature. If there is any thermal contrast remaining, it will be at floor level. The firefighter operating the thermal imager should direct the lens toward and across the floor as exits or hoselines may be visible (Woodworth, 1997b).

A firefighter must also be aware of thermal inversion when using an imaging device. When viewing from outside a structure, firefighters would appear on the display as white, or hotter than their surroundings. On entering the burning structure, the image would invert. The firefighters would now appear dark. This phenomenon is due to the imager viewing the firefighter as warm in comparison to the outside surroundings and cool when compared to the inside of a burning building. Thermal inversion can take place as a result of moving from room to room within a structure or changing the sensor’s position so that it points to the ceiling areas instead of the floor area within the fire room (Woodworth, 1997a).

With practice, a firefighter can view (determine) the level of the thermal layer and how fast it is falling. A good method to employ is comparing thermal layer with a place identified on the wall, such as the top of the window frame or door. When the heat conditions are developing rapidly, the firefighter should quickly identify any exits that could be used for egress (Woodworth, 1997a).

While the thermal imaging devices in use by the fire service today are very reliable they are still mechanical devices that are subject to failure. Firefighters operating these devices should still employ standard fireground practices that include carrying a powerful flashlight,

maintaining contact with a wall, and staying in communication with command. Good search practices such as looking under beds and on the other side of furniture will greatly enhance a firefighter's chance of success (Woodworth, 1997c).

Communication is a basic trait that must be employed when conducting successful thermal imaging operations. The firefighter operating the thermal imager must keep the team members aware of hazards and developing conditions. At a minimum, the firefighter operating the imager should be equipped with a portable radio and stay in constant contact with the incident commander. Being in radio contact with the incident commander will allow for the updating of conditions, directions, and heightened awareness, both from inside and outside of the fire building ("Image Is Everything," 1998).

PROCEDURES

Methodology

This research project employed evaluative research methodologies to identify the various practices and procedures being employed by various fire departments and firefighters that have used or are currently using thermal imaging cameras. The desired result was to identify the uses, practices, and procedures relating to the utilization of thermal imaging equipment that would most assist the firefighters and staff of the Village of Mundelein Fire Department in effecting a positive outcome when responding to assist our citizens. Once the uses, practices, and procedures were determined, the goal of this research was to produce a workable standard operating procedure that would provide the firefighters direction in determining when to employ, how to insure operability, and how to utilize the FireFLIR™ thermal imaging cameras that were recently acquired.

Literature Review

The literature review was begun at the National Fire Academy's Learning Resource Center during April of 2000. Subsequent materials were obtained from the Learning Resource Center through the U. S. Postal Service. An additional literature review was conducted in June of 2000 at the Fremont Public Library in Mundelein, Illinois and materials were supplied through the Interlibrary Loan Program. In addition, a variety of trade journals regularly received and utilized by this author were employed in this research project. A diligent effort was made to obtain and review various standard operating procedures related to thermal imaging cameras that were adopted by other fire departments.

The literature review targeted trade journals, magazines, and standard operating procedures relating to thermal imaging cameras that contained information regarding the operation, utilization and deployment of the devices. Those sources pertaining to this research were summarized and included in the literature review section of this report.

Assumptions

The procedures used to complete this research project were based upon the assumption that the various authors included in the literature review had completed a thorough and objective investigation when preparing their work. Second, it is assumed that the information provided by the various manufacturers of thermal imaging cameras was unbiased. Third, it is further assumed that the information provided by the other agencies currently using thermal imaging cameras was based upon actual successful and recommended practices that have been tried and proven. Finally, it is also assumed that as this technology becomes more affordable, and a

growing number of fire departments begin utilizing this equipment, additional information will become available that could impact this research.

Limitations

This research was limited by the relative age of the technology and the limited number of fire departments that have acquired this equipment. While this technology first became available to the fire service in the early 1970's, it did not gain widespread acceptance by the fire service until 1995. As these devices become more affordable, and the benefits associated with the utilization of this equipment are realized, many additional fire departments will obtain these devices. This will result in a greater volume of data becoming available for research purposes.

RESULTS

Answers to Research Questions

Research Question 1. What practices are recommended to insure the readiness of thermal imaging cameras for emergency operations? Several items were identified relating to the maintenance of thermal imaging cameras. The primary consideration is insuring that personnel that will be using the equipment are trained in its operation and use. This training must include both classroom familiarization and theory in addition to actual operation of the device in controlled fire training scenarios.

The second practice involves insuring that the camera is regularly inspected. Inspections insure that the thermal imaging camera is free of damage that could cause it to fail or work at a

less than optimal level. The inspection would include insuring that all warning labels are applied and legible. Inspections include viewing the camera for damage and insuring that the camera controls are correctly set for the type of situations most commonly responded to by the jurisdiction. Batteries should also be inspected for leakage or deterioration and periodically installed in the camera to insure condition. Inspection of the thermal imaging camera should include the powering up of the camera to insure operation of the circuitry and enable the firefighter to verify that the camera is operational.

The camera lens also requires maintenance. The lens and display area should be cleaned per the manufacturers recommendations after each use and protected with an anti-fog solution. Cleaning the lens insures that the lens will be able to receive the maximum amount of infrared radiation the camera is designed to receive. This will result in the camera producing the optimum image for which it was designed.

The research also found that should the camera be inoperable, defective, or damaged, it should be returned to the manufacturer for repair.

Research Question 2. In what emergency situations is it appropriate to employ thermal imaging cameras? This research identified that thermal imaging cameras can be employed whenever it would be beneficial to determine the amount of infrared radiation being emitted, with one notable exception.

It was identified that thermal imaging equipment has been successfully employed in many firefighting tasks. The tasks identified are size-up, search and rescue, fire attack, reducing fire damage, reducing water damage, reducing overhaul damage, identifying openings in floors,

ceilings, and roofs, identifying trip and fall hazards, wildland firefighting, and identifying signs of potential structure collapse.

Thermal imaging equipment was identified as being beneficial at the scene of non-fire emergencies. Such emergencies include hazardous materials response, tracking hazardous material spills, aircraft accidents, locating victims of transportation accidents, electrical over current or overheating incidents, lightning strikes, and night operations.

It was determined that thermal imaging equipment not certified as intrinsically safe should not be employed at incidents where a potentially explosive atmosphere exists. Thermal imaging equipment will not function when attempting to locate persons or items below the surface of water or through glass.

Research Question 3. What procedures should be followed when operating a thermal imaging camera? This research identified several procedures that should be included in the operation of thermal imaging equipment. Chief among the procedures identified is the need for personnel to recognize, interpret, and take action when the thermal imaging cameras built-in warning devices activate. It was also identified that firefighters will need to continue training in traditional methods not utilizing thermal imaging equipment.

When the thermal imager warning devices activate, it indicates that the camera has become unstable and unreliable. Upon activation of any of these warnings, the firefighting team must cease operations and exit the building as the imager is about to shut down. Traditional firefighting skills and methods must be maintained to provide for the safety of our firefighters should the camera shut down while the firefighters are in a tenuous situation.

It was identified that the FireFLIR™ camera is capable of being operated in either a hand-held or helmet-mounted mode. When it is necessary or anticipated that both hands will be needed to accomplish a given task, the helmet-mount method should be utilized. In other situations such as overhaul, hazardous materials operations, and electrical emergencies, it may be used in the hand-held mode.

Three search techniques were identified. They are the Point-To-Point Search technique, the Oriented Search technique, and the IR-Led Search technique. While each technique is effective, it appears that the Point-To-Point Search would be the most effective for the Mundelein Fire Department to employ.

It was also identified that a systematic scan of a room is necessary when utilizing the thermal imaging equipment. The technique discussed, the Six-Sided Technique, would appear to be effective in providing firefighters the ability to check entire areas from floor to ceiling for victims, structural degradation, fire extension, and hazard locations.

The research identified the need to train the firefighters to interpret the images presented in the display. It is necessary to be able to identify flashover, thermal inversion, and the level of the thermal layer. Training should be provided regularly to reinforce how these images will present on the display.

It was further identified that continued maintenance of and training in traditional firefighting skills and techniques is required to provide for the safety of the firefighting team as well as all firefighters on the scene. Communication between the team members and the two-way communication between the team and the incident commander is also essential for conducting successful firefighting operations.

It is the goal of this research to develop a standard operating procedure for the Village of Mundelein Fire Department that will govern the maintenance, use, and application of thermal imaging cameras.

DISCUSSION

Humphry confirms the importance of having an operational guideline for the maintenance, use, and deployment thermal imaging equipment. Humphrey, (2000, p. 12) revering to thermal imaging technology writes “In firefighting, however, maximizing the advantages of this advanced technology will probably require assimilating it into our standard operating procedures.”

Humphry, (2000) also offers a sample standard operating procedure. In reviewing the standard operating procedure produced in conjunction with this research, many of the items proposed for inclusion by Humphry are included in the standard operation procedure produced as a result of this research. The article included items in the categories of use, operation, and maintenance. This research has found that these three categories are the basis for preparing such a standard operating procedure.

This author feels that this research has led to the development of a standard operating procedure that will benefit the Village of Mundelein Fire Department. This standard operating procedure will provide direction to the firefighters when operating, maintaining, or determining when and how to deploy the Fire FLIR™ thermal imaging cameras. This procedure will also require that firefighters be trained to a minimum standard as determined by the training division prior to operating or utilizing the thermal imaging equipment.

It is the hope of this author that the standard operating procedure produced as a result of this research will provide direction to the firefighters, thereby enabling our firefighters to utilize this equipment in a safe, proficient, and efficient manner. Following this procedure will ultimately benefit our citizens of our community by reducing fire loss, reducing damage, and providing improved service in a variety of other situations.

RECOMMENDATIONS

Recommendation 1. As training is a necessary part of all successful fire service programs, it is incumbent that the Mundelein Fire Department Training Division begins the process of preparing a training standard that will define the behavioral objectives needed to operate thermal imaging equipment. Additionally the standard should contain requirements in interpreting the images expected as a result of utilizing the thermal imaging cameras. Finally, the standard should specify that fire personnel demonstrate their proficiency in using and interpreting the images produced by participating in controlled, live burn training activities.

Recommendation 2. Should a fire service standard relating to thermal imaging cameras is developed, the standard operating procedure which has been produced as a result of this research should be reviewed to insure conformity with industry standards and procedures.

Recommendation 3. The utilization of thermal imaging equipment is relatively recent in the fire service. While it was first introduced for limited use in the 1970's, this equipment has only been readily available for the past five years. During these few years, major changes have taken place in the field of thermal imaging. Today's imagers are lighter, more reliable, and technologically advanced to the imagers produced just five years ago. It is expected that improvements will continued to be made in the near future. As these improvements are made

and they become available, the standard operating procedure pertaining to thermal imaging will require review, modification, and updating.

Recommendation 4. It is recommended that the fire service as a whole support the development of a national standard pertaining to thermal imaging equipment. While many articles have been written and several operating procedures been produced, a standard is needed to govern thermal imaging devices on an industry-wide basis.

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APPENDIX A

APPENDIX A
MUNDELEIN FIRE DEPARTMENT
OPERATING PROCEDURES

SECTION 13.2.22_____

FIELD OPERATIONS

EFFECTIVE: 10/16/2000

ATTACK OPERATIONS

REVISED

THERMAL IMAGING CAMERA

PAGE 1 OF 4

PURPOSE:

The purpose of this standard is to assist personnel in: 1) Determining when to employ thermal imaging equipment at the scene of an emergency incident, 2) Maintaining the FireFLIR™ thermal imaging camera, 3) Operating the FireFLIR™ thermal imaging camera.

POLICY:

Use of thermal imaging equipment

It is the policy of this department to utilize thermal imaging equipment at every structure fire and at any incident where the use of thermal imaging has the potential to enhance the outcome of the operation. It may be appropriate to use thermal imaging equipment for:

- Size-up
- Fire attack
- Search and rescue
- Reducing fire damage
- Reducing water damage
- To assist in overhaul
- Identifying openings in floors, ceilings, and roofs
- Wildland firefighting
- Identifying signs of potential structural collapse
- Electrical emergencies
- Odor emergencies
- Hazardous materials response
- Transportation incidents (identifying hazards or locating victims)
- Aircraft accidents
- Darkness or low light situations

- To assist in navigating
- To locate lost persons in open areas
- Any situation that could be improved through the use of thermal imaging

Thermal imaging equipment is not be used for:

- Locating victims below the surface of water
- Attempting to see through glass
- In explosive atmospheres

Maintenance of the FireFLIR thermal imaging camera

The FireFLIR™ thermal imaging camera shall be maintained ready for use at all times on each first due engine companies. The cameras shall only be maintained by firefighters that have received training on the upkeep of the device.

Daily Maintenance

Daily maintenance shall include: insuring that the camera is present and secure in its mounting bracket, insuring that the camera is free of damage, insuring that the camera is clean, insuring that the lens is clean, insuring that the camera operates when energized, insuring that 3 batteries are in each charging pallet and that a fully charged battery is attached to the camera (but not in the locked or connected mode). Batteries should be inspected to insure that they are free of damage or leakage. Once the camera is determined to be operational, it will be powered up and the firefighter inspecting the camera will insure that the battery icon indicates the battery is at full charge and that the internal temperature overheat icon is not on. If any damage or defects are found, a maintenance form shall be completed and forwarded to the Shift Commander.

Weekly Maintenance

Each Wednesday, the firefighter performing the inspection of the thermal imaging camera shall insure that the “Range Switch” is set in the auto mode and that the “Color Switch” is set to the black and white mode. At this time, the firefighter will clean the lens and display area, and apply an anti-fog solution to the lens and the display. The firefighter will insure that all warning labels are in place and discernable per the manufacturers guidelines. Guidelines for the placement of required warning labels are available in the FireFLIR™ Orientation Manual.

After Each Use

After each use, the Engine Officer will insure that both the weekly and daily maintenance procedures are performed as outlined in this procedure.

Damage

Should the camera fail or damage be noted, the FireFLIR™ thermal imaging camera will be removed from service, reported to the Shift Commander. The Shift Commander will notify the Deputy Chief who will be responsible to insure that the unit is immediately shipped to FLIR

Systems, Inc. for repair. Under no circumstances shall the case of the FireFLIR™ thermal imaging camera be opened. There are no user serviceable parts contained inside the camera. Should the camera be taken out of service, it will be placed in the custom carrying case provided in order to protect the camera from further damage.

Operational guidelines for the FireFLIR™ thermal imaging camera

Thermal imaging equipment shall only be operated by personnel that have received training on the FireFLIR™ thermal imaging camera as provided by the Training Division. Under no circumstance shall untrained personnel attempt to operate the camera.

Once determined the FireFLIR™ thermal imaging camera will be used, the camera may be operated in one of two ways. The helmet-mount method shall be employed for size-up, search and rescue, and fire attack. In all other instances, it is recommended that the helmet-mount method be utilized unless the operation will exceed 20 minutes in duration. Incidents other than those involving size-up, search and rescue, and fire attack that exceed 20 minutes in duration may make use of the hand-held method.

The Officer assigned to the apparatus will also serve as the operator of the thermal imaging equipment.

When ready to deploy the FireFLIR™ thermal imaging camera, the battery should be slid into position to make contact with the circuitry. The user should insure that the battery locks into place. The camera will begin initializing and a red screen will appear. Once initialization is complete, the user should insure that the battery is fully charged by checking the indicator on the visual display. If the battery is not indicated to be fully charged, the battery should be replaced by inserting a spare battery. User will also check to see that the internal temperature indicator is not visible. Should either the battery indicator or internal temperature icon indicate a problem, the thermal imaging camera shall not be used.

Any firefighter operating the FireFLIR™ thermal imaging camera will take a spare battery from the charging pallet and place it in their pocket. If the original battery should fail, it will be immediately replaced.

When exiting a building to recharge the breathing apparatus, the operator will obtain a fully charged battery from the charging pallet and replace the battery in the camera. The used battery will be placed on the Officers seat.

When entering a building or room, the firefighter operating the FireFLIR™ thermal imaging camera will employ a six-sided scan of the room. The firefighter will begin scanning the room starting at the extreme upper right, near the ceiling. The firefighter will scan at the room at this level until the camera has reached the extreme upper left. The firefighter will then lower the aim of the camera to the mid-point of the extreme left wall and scan from that point to the extreme right. The firefighter will again lower the lens to the floor level and scan from extreme right to extreme left.

When employing the thermal imaging camera for search and rescue operations, firefighters will employ the Infrared (IR) Led Search method. The Officer, wearing the FireFLIR™ thermal imaging camera will select a point inside the structure or area and lead the company to that area while maintaining contact with the wall. The company, with the exception of the officer (operating the camera) will employ traditional search techniques in accordance with instructions provided by the Officer.

Personnel utilizing the thermal imaging equipment shall at all times anticipate that the FireFLIR™ thermal imaging camera may malfunction or cease functioning. While this is an infrequent event it is a possibility. If the company experiences imager failure, the company shall immediately withdraw from the building utilizing traditional techniques. At no time should a firefighter attempt to stand while inside utilizing the thermal imaging device.

Firefighting personnel shall comply with the training procedures issued by the Training Division relating to interpreting images and understanding thermal inversion.

All company members assigned a thermal imaging camera shall demonstrate good communication skills. The thermal imaging camera operator shall keep his company fully informed regarding their progress, any hazards noted, and changing conditions. The search team shall also maintain two-way radio contact with the Incident Commander at all times.

The Officer must be aware that employing this device can significantly reduce the time required for search an area and result in personnel entering deeper into the structures. The Officer and each team must remember to focus on their ability to extricate the team from the structure should the imager fail.

Fire Chief